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The Mernda VR Project: The Creation of a VR Reconstruction of an Australian Heritage Site

CASE STUDY

THOMAS KEEP

ubiquity press

ABSTRACT

The Mernda VR Project is an initiative exploring the possible applications of hypothetical digital reconstructions of rural archaeological sites, with an aim to investigate the efficacy of virtual reality as a means of fostering engagement and interest in rural archaeology. Expanding on existing work into digital reconstructions of heritage, the Mernda VR Project investigates whether reconstructions of heritage sites may be suited to smaller scale rural archaeology, in addition to reconstructions of grander, more well-known, and celebrated heritage sites. While reconstructions of renowned heritage sites certainly have their place in engaging the public with heritage, rural archaeological heritage is at a greater risk of destruction resulting from development, or simply being overlooked and forgotten in the public imagination. As such, these sites are in greater need of innovative representations and outreach programs for their cultural merit to be understood and remembered. The Mernda VR Project used physically based rendering (PBR) to create a life-like digital environment reconstructing a mid-19th century cottage and flour mill in Mernda, Victoria, and imported the 360 degree rendered images into the virtual tour software 3DVista for development into an interactive educational experience. The experience is planned for display in local schools to assess the practicability and effectiveness of such displays for increased engagement, interest, and comprehension compared with more traditional educational displays. This article is intended as a technical guide for the creation of 3D modelled archaeological displays using polygonal modelling and PBR textures and structure from motion photogrammetry, and acts as a companion piece to Keep (in press) which provides further details on the historical context of the reconstructed site.

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1. DIGITAL REPRESENTATION AND HERITAGE

3D digital representation of archaeology is a progressively developing field of interest in heritage studies, with a variety of possible functions and promising applications for the research of the past and the promotion of heritage. The application of these new forms of media has been progressively adopted since the turn of the millennium in the recording, analysis, and display of heritage materials (Garstki 2017: 727; Fritsch and Klein 2018: 9153). The potential of digital applications in archaeology is truly vast, ranging across the close inspection of the minutiae of artefacts, the re-experiencing of the excavation process (Di Gravio and Hardy 2018: 218), the sharing of archaeological experiments (Eve 2012: 586), and the simulation of phenomenologically embodied experiences in digitally reconstructed landscapes (Eve 2012; Galeazzi 2018: 274; Demetrescu et al. 2020: 128).

The use of VR to restore, reconstruct, and visualise ancient monuments is now a decades old method for engagement and interpretation, with a notable increase in interest since the new millennium developing alongside ever-increasing technological capacities (Ch'ng 2009: 458). Ch'ng (2009) overviewed a wide array of projects from across the world, which included both large scale world famous monuments as Stonehenge, as well as VR reconstructions of mid-scale sites such as the village of Shirakawa-go in Japan. However, an overview of the field to date indicates that the primary focus and application of VR reconstructions has been in the service of visualising grand, renowned, and spectacular monuments of world heritage, with the technology being leveraged chiefly in the interest of producing a "wow factor" (Galeazzi 2018: 273; Kantner 2000: 47; Douglass et al. 2019: 127). This overemphasis on grandeur has attracted sufficient concern to warrant codes protecting against it, with principle 5 of the Seville Charter for computer-based visualisations of archaeological heritage advocating specifically against reconstructing archaeological sites only in a period of splendour rather than showing periods of decline or alternate phases of their history (Lopez-Menchero and Grande 2011: 4).

Less common is applying these reconstructive techniques in the interest of promoting smaller, rural heritage sites. Within Australia, there is an acknowledged concern of outmigration from rural towns, which threatens a loss of character, identity, and cultural capital (Walmsley 2003: 61). A five year State of the Environment report noted that 54 historic places had been removed from heritage register as a result of destruction or loss of values, with the potential threat of a 10–15% loss of extant heritage places by 2024 (National Incentives Taskforce for the EPHC 2004: 2). Remote historic heritage within Australia has faced difficulties in funding and public attention, receiving an interest far in arrears of its historical significance to the development of the modern Australian culture and identity.

Rural sites are often regarded as too difficult to conserve for public visits, with a potential feedback loop forming wherein lack of knowledge about rural heritage diminishes interest in preservation, which in turn restricts opportunities for the public to engage with their heritage and develop interest in it. Sites of early colonial pastoral

Figure 1 Render of the 3D modelled site featuring the Yan Yean Aqueduct, Moses Thomas Mill, the mill cottage, and the natural environment.

or agricultural technology in particular have been noted as insufficiently represented in heritage registers, with evidence such as fencing, mills, dams, and paddocks often unlikely to meet the formal requirements for heritage listing and protection (Lennon 2011: 26). The tendency for VR reconstructions to focus on grand and monumental sites threatens to perpetuate or even exacerbate these imbalances in representation, forming an implied "authorised heritage discourse" (Douglass et al. 2019: 127; Smith 2006). However, the reverse is also possible: in the absence of physical conservation and display of these sites and often the threat of destruction, hypothetical reconstructions in digital environments may provide an alternative option for 'preservation' and outreach to the public. The Mernda VR Project was conceived in the interest of exploring the potential for VR reconstructions of smaller, more ephemeral sites to counteract the potential threat of VR further establishing a monumental-focussed public archaeological narrative.

2. THE MERNDA VR PROJECT

The Mernda VR Project is an exploration of the applications of hypothetical virtual reality reconstructions of rural Australian heritage. It seeks to consider the capacities of 3D modelling, photogrammetry, and virtual reality for heritage co-ordinators to facilitate ongoing outreach of excavated heritage in cases where open air preservation of the site is impractical. The project created a hypothetical reconstruction of the Mayfield Mill of Moses Thomas and its attendant cottage along the west bank of the Plenty River in Mernda, Victoria. The project used archaeological finds, photographic evidence, and appropriate comparanda in conjunction with 3D modelling, photogrammetry, and Geographic Information System (GIS) data to create a life-like digital environment. This digital environment was rendered as a stereoscopic 360° panoramic image which was imported into the virtual tour package 3D Vista Virtual Tour Pro (Version 2021.2.16; 3D Vista Pro 2021) where viewers can experience the reconstruction in an immersive environment with a virtual reality headset, or view it on a desktop computer or flatscreen device. Interactive elements were incorporated to increase a sense of engagement and active learning.

2.1 SITE DETAILS

The Mayfield Flour Mill was established by the engineer Moses Thomas in 1855 along the west bank of the Plenty River (Honman et al. 2013: 23) upstream from the existing Carome and Janefield mills (Vines 2017: 514–520). In the mid 19th century, the mills of the Plenty River were an important supply source to both the local region and the growing population of Melbourne (Jones 1990: 94.; Vines 2017). The region of Whittlesea had been occupied by agricultural colonial settlers since the 1840s, ousting the European pastoral squatters who preceded them (Honman et al. 2013: 16). By the 1850s, the region was considered "the second most important district in the colony" (Honman et al. 2013: 8–12). In addition to providing flour, the area provided a significant water supply to Melbourne via the Yan Yean Aqueduct constructed in 1853 (Ritchie 1934: 379), crossing the Plenty River to the south-east of the cottage (Smith et al. 2016: 88). The mill was partially excavated by Heritage Victoria alongside a fuller excavation of the associated attendant's cottage in 2015 (Tucker et al. 2016; Smith et al. 2016). Further historical and archaeological details can be found in Keep (in press), Smith et al. (2016), and Tucker et al. (2016).

2.2 PROCESS

The digital reconstruction of the site was created through a combination of polygonal and procedural 3D modelling from reference images and collected samples (with models textured and rendered using physically based rendering), structure from motion photogrammetric modelling of original artefacts, and procedural 3D modelling using digital elevation models. Assets were created separately and combined within a single Blender project file, where they were arranged to give an appearance of the site as it may have looked during the mid 19th century. Cameras placed into the scene were used to render out stereoscopic 360° images which can be viewed on a VR headset, displayed as 360° videos on platforms such as YouTube, or imported into virtual tour software packages such as 3DVista. These assets can later be imported into video game engines and associated with physics systems within the engines to create interactive navigable environments for users to explore.

All modelling, texturing, and rendering was undertaken by the author using skills developed part-time over the span of two years, demonstrating that it is well within the capacity of interested digital archaeologists to develop 3D modelling skills to create their own hypothetical reconstructions. Techniques within Blender (Version 2.93.3; Blender 2022) were learnt through the 'Creating 3D environments in Blender' tutorial hosted on the online learning platform Udemy (Tuytel and Rahman 2020), in combination with the many excellent tutorials freely available on YouTube. More detailed models could be made by collaborating with professional 3D artists.

2.2.1 Buildings

Cottage

The mill attendant's cottage was the primary focus of the 2015 excavation of the site undertaken by Heritage Victoria. It was built in 1855 to house the attendant of the nearby mill, constructed at the same time (Smith et al. 2016: 82). The cottage is partially visible in an 1878 photograph (See Smith et al. 2016: 893), and features a brick chimney, wooden walls, and a veranda common in early colonial Australian architecture. Period appropriate comparanda was consulted in the reconstruction process (Keep In press).

As only the bluestone foundations, remnants of a brick veranda floor, and brick chimney foundations of the cottage remained in-situ, the model was created entirely within Blender without using any photogrammetric modelling. The dimensions of the cottage were deduced from the floor plan provided in the excavation report (Smith et al. 2016: 84) and the elevation of the roof was estimated on the basis of comparanda and the existing historical photograph (see Figure 2). The main body and roof of the cottage was modelled as a single object with multiple textures applied to different sections, while individual elements such as the veranda beams and windows were modelled individually and duplicated as necessary.

Physically based rendering (PBR) textures were used to allow image textures to modify the geometry of the structure procedurally to reduce time spent modelling and the processing load of the Blender scene. A subdivision surface modifier was used to add vertices to otherwise flat and featureless surfaces with a displacement image used to modify the geometry according to data derived from the PBR textures. This workflow created a more realistic, varied, and 'textural' surface appearance without excessive modelling and rendering time investment. The same process was used to add texture to bricks, wood beams, wood slats, and roof tiles. The resulting complexity transformed otherwise flat and lifeless surfaces into a more realistic result (Figure 3).

Other Structures

In addition to the cottage, the mill and nearby aqueduct were modelled to create a more immersive interconnected scene rather than an isolated cottage. These structures are less thoroughly excavated than the cottage. An 1878 etching by Samuel Calvert (Figure 4) depicting both structures served as the primary reference for reconstruction, while relevant comparanda provided the details, in place of primary archaeological data. Historical photographs of the nearby mills provided comparanda for design, and there were sufficient archaeological remains to determine that the structure was built primarily in bluestone with a brick chimney (Vines 2017: 525), similar to other mills of the region

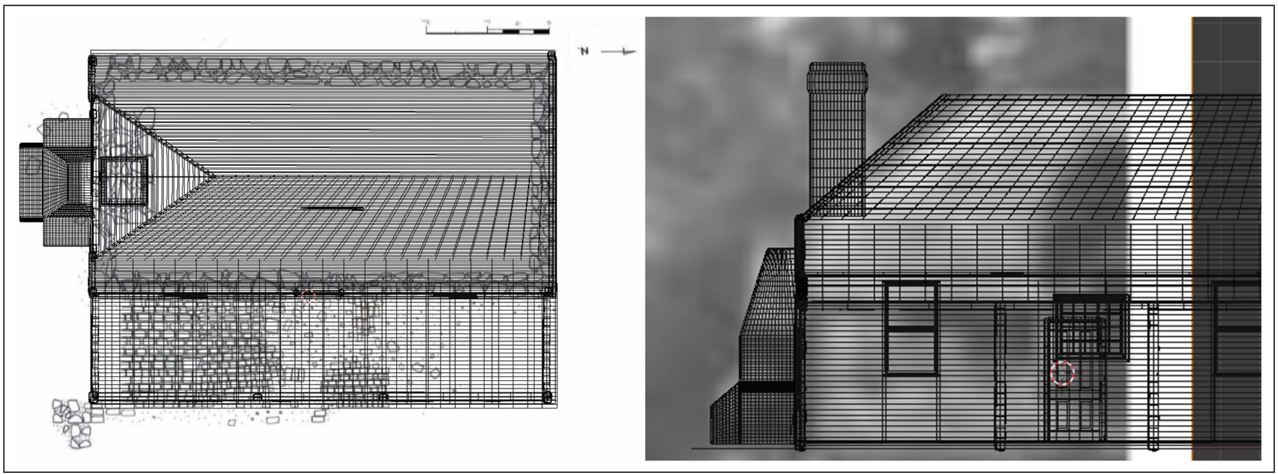

Figure 2 Comparing the model proportions to the foundations and historical photograph.

Figure 3 Simple texture(left) and texturing with displacement (right).

and period. The mill and aqueduct were, like the cottage, modelled using polygonal modelling and rendered with PBR textures using a displacement modifier (Figure 5).

2.2.2 Objects

A selection of key artefacts from the site were chosen to be 3D modelled and included in the reconstruction on the basis of their historical significance, completeness, the availability of reference images and comparanda, and the degree to which they were likely to interest and engage audiences. Most of the digitally reconstructed objects were created using both polygonal 3D modelling from reference images and structure from motion photogrammetric modelling of the excavated artefacts. This dual modelling process was explored to facilitate a comparison between the hypothetical digital reconstruction and the present day state of the excavated materials, providing an immediately comprehensible connection between excavated materials and the original site. Access to the original artefacts was generously provided on request by Heritage Victoria.

Modelled objects were included in the Blender project file of the scene, placed in a naturalistic way around the site to give the appearance of a lived-in environment, although not necessarily associated immediately with their find spots. Animated videos of the objects rotating were used in hot-spot pop-ups within 3DVista, allowing audiences to inspect elements in closer detail, and in some instances see how they may have been used during their pre-depositional life.

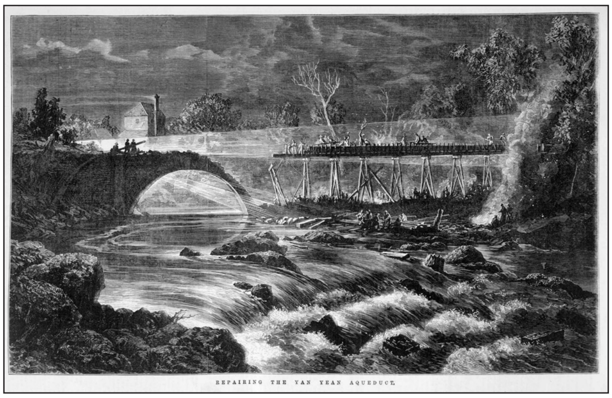

Figure 4 Samuel Calvert's 'Repairing the Yan Yean Aqueduct' (1878). Printed in the Illustrated Australian News. State Library of Victoria: Ebenezer and David Syme Collection.

Marble

A single hand painted ceramic marble decorated with concentric circles painted in red, green, and purple-brown was recovered from the site during excavation (Tucker et al. 2016: 47). This find was considered of high significance in the interpretation of the site, as its decoration indicates that it was neither a bottle stop nor used in blind baking, but was specifically made as a children's toy. This indicates that the site was not only at least partially domestic, but was a family dwelling with a child present at some point during its occupation.

The marble was modelled using both photogrammetric modelling of the original artefact (Figure 6) and using PBR modelling from reference images within Blender (Figure 7). Digital photography using a stationary tripod-mounted Nikon D5300 was conducted inside a light-box

Figure 5 Render of the mill, aqueduct, and cottage.

using a bluetooth connected Foldio 360 turntable for semi-automated photography. An X-Rite ColorChecker Passport card was photographed alongside the object, with the associated colour calibration software used to maintain colour fidelity in Adobe Lightroom Classic 11.5, as recommended by Gaiani et al. (2017). Minor adjustments were made to the images within Lightroom (Table 1) to reduce the impact of glare and provide more texture for Agisoft Metashape Standard 1.8.2 (Agisoft 2022) to identify. As complete photographic coverage of the marble was impossible with the underside obscured as the marble rested on a surface, the model was produced in two sections (termed 'chunks' in Agisoft Metashape) which were subsequently merged together. The automatic process provided by Agisoft Metashape created a misalignment, and so manual alignment by eye was necessary before the halves were merged. The merged model was retextured using the complete image set for both halves of the marble. The division line between the halves is almost imperceptible, and would certainly not be noticed on the scale at which the model will be viewed (Figure 6).

Figure 6 Photogrammetric model of marble. Model created in Agisoft Metashape, image rendered with artificial lighting in Blender.

The hypothetical reconstructions of the marble were modelled by hand in Blender, then imported into a scene featuring a dirt circle with modelled grass in imitation of the game of marbles. These models could be animated to collide with one another, to demonstrate in a short animation their function as a toy. This animation was rendered within Blender and incorporated as a video in presentations (Figure 7).

Pipe Bowl

Considered the most notable find recovered from the site by the excavators (Tucker et al. 2016: 52), a clay pipe bowl moulded in the shape of an imperial soldier was found in the mill excavation. Clay pipe use was widespread across 19th century colonial Australia, and often acted as a signifier of class (Gojak and Stewart 1999: 40). The presence of this pipe on the site not only indicates the working class identity of the inhabitants on the site, but also suggests by its design a continuing cultural affiliation with imperial Britain by its owner.

Figure 7 Hypothetical reconstructions of marbles with a dirt ring for animation Modelled and rendered in Blender.

An attempt was made to model the pipe within Blender before access to the original was available for photogrammetric modelling, but after several attempts the level of detail on the face and helmet proved beyond the author's current ability as a 3D modeller. The face in particular proved exceptionally challenging. Likely a result of the human brain's highly tuned capacity to recognize minute differences between faces, any model produced by hand would have to be of high quality to stand-in for the original, and it was decided that only photogrammetric modelling or a hired professional 3D artist would be capable of completing the task to a sufficiently life-like standard.

Access to the original was eventually possible after COVID lockdown restrictions had been eased. Photography was completed as above using a turntable and lightbox with colour correction, and minor adjustments in Lightroom (Table 1). As with the marble, complete photographic coverage was impossible, and the model had to be completed in two merged sections. Modelling the pipe-bowl interior presented a particular challenge, and bright lighting was used in an attempt to have this section modelled successfully. The interior walls were successfully modelled by Agisoft Metashape, however the lowest sections of the bowl were insufficiently lit, resulting in improper geometry and digital artefacts. Rather than leave this section as is, or obscure it from view, it was decided instead to recreate an estimate of the original interior geometry within Blender. A simple half-sphere mesh was joined to the distorted interior, and the texture from other sections of the pipe bowl walls was applied. Additionally, it was noticed while in Blender that the two halves were not evenly lit, with the upper half brighter than the lower: a result of the bright lighting used in an attempt to make the interior visible. To compensate for this, the texture for the lower half produced by Agisoft Metashape was adjusted within Blender for brightness and contrast, until it matched the texture produced for the upper half (Figure 8). The edited model was exported as a Graphics Language Transmission Format Binary file (.glb) so that these changes to texture would be embedded into the model itself. This model is currently available on Heritage Victoria's SketchFab page (Heritage Victoria 2022).

Figure 8 Photogrammetry model of the pipe bowl. Model created in Agisoft Metashape, image rendered with artificial lighting in Blender.

Perry Davis Painkiller

A single bottle of Perry Davis's Vegetable Painkiller, identified by the embossed glass text, was uncovered during excavation. Perry Davis's Painkiller was an American opiate serum marketed internationally from the 1840s onwards (Tucker et al. 2016: 53), part of a larger market of unregulated curative formulas concocted and distributed in the late 19th century (Petty 2019: 264) period of laissez-faire industrial capitalism. The find is indicative of the connection of the occupants of the rural site to wider international trade networks, as well as providing further evidence for a working-class labourer identity for the occupant of the cottage as Perry Davis' Painkiller was heavily marketed in Australia and New Zealand to workers such as miners and labourers (Petty 2019: 264) as the 'trusted friend of the mechanic, farmer, [and] sailor' (The New Zealand Herald 18 October 1881: 7).

The bottle was found complete and in a relatively good state of preservation, although the cork and label had long since been lost. Glass is a notoriously difficult material to model using photogrammetry alone, as the translucency and reflectiveness wreak havoc on image alignment. These issues can be surmounted through the use of scanning sprays or combining photogrammetry with X-ray CT scanning (Fried et al. 2020). Due to the delicacy of the opalised patina on the surface of the glass, the sprays available were considered inappropriate, and access to a CT scanner was not available. However, the patination of the glass did substantially reduce its translucency, and so an attempt was made to model the bottle using a standard photogrammetry workflow. Low lighting was used to reduce the impact of glare, with a longer exposure time to compensate (Table 1). Minor adjustments were made within Lightroom (Table 1), and the model was completed in multiple chunks which were successfully combined using Agisoft Metashape's automated alignment. The final model presented better than anticipated, however there were inevitable warpings, aberrations, and digital artefacts that distorted the model. The material settings for the render in Blender were mixed with a combination of the image texture generated in Agisoft Metashape and a transparent BSDF (bidirectional scattering distribution function) node in Blender to reduce the opacity of the model and provide a greater sense of its original appearance.

Given these predicted difficulties in producing a photogrammetry model of the glass bottle and the reality of the tarnished patinated surface and lost labels, cork, and internal fluid, it was decided to create a 3D reconstruction within Blender depicting how the bottle may originally have appeared. Reference images of better preserved bottles were sourced online, and compared with the example from the site to ensure the correct design was used. From here, a replica was modelled within Blender, using the wireframe view to check proportions (the same process seen in Figure 2). Thickness was added to the 3D modelled bottle, and a volume was added internally to represent the medicinal concoction itself. PBR texture images sourced online were used for the cork material, while the materials for the glass and internal fluid were created using Blender's internal 'Principled BSDF' shader. The labels were added to the bottle as flat planes, which were textured using images sourced online of well preserved examples. Text geometry was added within Blender using the 'add thickness' modifier to create the raised sections on the bottle which read 'DAVIS', 'VEGETABLE', and 'PAINKILLER'. The final result depicts a highly life-like representation of the original bottle with cork, labels, fluid, and untarnished glass (Figure 9).

While neither the photogrammetry model nor the polygonal modelled hypothetical reconstruction are perfectly accurate representations of the original, when presented together they can provide audiences with an understanding of the conceptual link between artefacts and originals, revealing the process of archaeological inference while also building a sense of realism in the overall site reconstruction. A version of the reconstruction model is available on the author's personal SketchFab page (Keep 2022c).

2.2.3 Nature

An important element of the site is the surrounding natural environment, which played a significant role in how the landscape was perceived and understood by colonial settlers (Collingwood-Whittick 2008). Even today, the looming figures of the red gums characterise the landscape and play a significant cultural role in the locals' perceptions of their environment (*Northern Star Weekly* 2021), signified by an unsuccessful 2018 change.org campaign to preserve some of the region's oldest trees from removal as part of road upgrades. To present

Figure 9 Hypothetical reconstruction and photogrammetry model of Perry Davis Painkiller. Left hand figure modelled from reference images in Blender, right hand modelled in Agisoft Metashape. Image rendered with artificial lighting in Blender.

OBJECT	CAMERA DETAILS	LIGHT	PHOTOS	EDITING	MODELLING NOTES
Marble	Nikon D5300 55mm lens 1/8 shutter F25 aperture ISO100	Bright white	224	Colourchecked Exposure +0.5 Texture +30 Clarity +5 Dehaze +5	Manual alignment of chunks in Agisoft Metashape
Pipe bowl	Nikon D5300 55mm lens 1/15 shutter F20 aperture ISO100	Bright white	442	Colourchecked Exposure +0.5 Texture +30 Clarity +5 Dehaze +5	Manual alignment of chunks in Blender, retexturing in Agisoft Metashape, additional geometry added in Blender
Perry Davis Painkiller	Nikon D5300 55mm lens 1/15 shutter F20 aperture ISO100	Mid white	346	Colourchecked Contrast +10 Texture +30 Clarity +5 Dehaze +5	Automatic alignment in Agisoft Metashape. Added translucency in Blender.

Table 1 Photogrammetric modelling data.

only the models of the buildings and artefactual material detached from their surrounding environment would misrepresent how they were perceived in the past, and so the inclusion of trees, bushes, reeds, and grass was considered essential to the representation. This decision is in alignment with principles 4.4 and 4.5 of the Seville Charter which stress the importance of the natural environment in authentic and historically rigorous virtual reality representations of archaeological heritage (Lopez-Menchero and Grande 2011: 4).

Red Gums

The red gums of the region have had a long and significant history and their presence continues to play an important role in the cultural landscape. They had an important pre-contact role in Wurundjeri resource exploitation, providing bark for use in the production of shields and canoes (Ellender 1991: 9–11; Griffin et al. 2013: 62; Cumpston 2020: 18). In the early colonial period European settlers exploited red gums for timber, such that timber frames became standard for pioneer structures of the period (Marsden 1989). Within the City of Whittlesea, the presence of dense forests spurred the development of a timber industry which supported growing settlement (Honman et al. 2013: 31–33), particularly important during the 1850s gold rush where the timber was used for posts, rails, and palings (Honman et al. 2013: 19). The surrounding terrain of the Plenty Gorge Parklands is still spotted with these trees. The longstanding cultural significance and prevalence of this species made it a priority for inclusion in the virtual reality reconstruction.

The reg gums were created in Blender using procedural modelling and PBR texturing. The base model of the trunks and branches were generated using the 'Sapling Tree Gen' add-on which follows the method developed by Weber and Penn (1995). This add-on automatically generates a base tree model with branches, and provides options to modify the branch count, number of divisions, trunk height, and width, etc. Using red gum reference images from Google, the base model was modified until it resembled the general form of the species. A set of leaves and gumnuts were individually modelled within Blender from reference images of samples collected from nature and photographed against a white background. With these reference images imported into the background of Blender, a plane was extruded and edited to match the shape of the leaves (Figure 10). The same process was repeated for the twigs and gumnuts.

PBR texturing relies on a combination of images to inform rendering software of the necessary interactions of light and geometry (Iakushkin et al. 2018). These image include scatter/diffuse maps which describe the colour of the surface, normal maps which describe the surface relief, height maps that describe the deviation of the surface, ambient occlusion maps that describe shadows

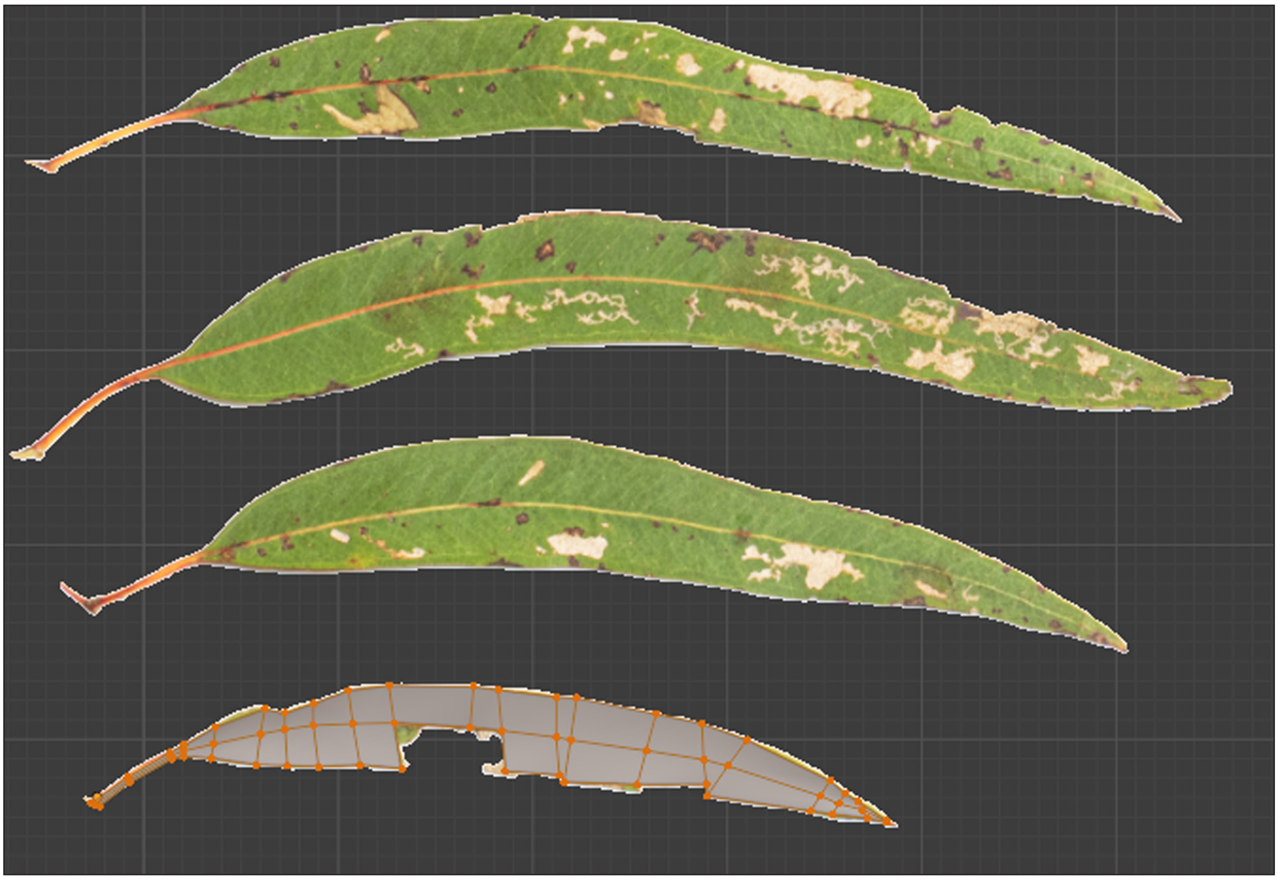

Figure 10 Modelling gum leaves.

created by surface detail, and specular or metallic maps that describe the intensity of light reflected from the surface (Iakushkin et al. 2018: 464–465). Thousands of these PBR textures are available for thousands of different surfaces freely or inexpensively on the internet, however for highly specific surfaces for niche applications, such as the appearance of a gum leaf, they can be difficult or impossible to find. It was therefore necessary to generate my own PBR texture maps (Figure 11).

This was completed using 'Materialize', an open source tool produced by Bounding Box Software which generates the PBR textures from imported images while allowing users to modify and adjust the generated textures (Figures 12 and 13). These textures were applied to the modelled leaves, which were then duplicated and modified to provide a variety of alternatives. The leaves were manually placed along a modelled twig, which was itself duplicated and modified. This process resulted in a selection of distinct branches from the base assets, so that duplicated models would not be noticeable, providing a more natural, organic appearance (Figure 14).

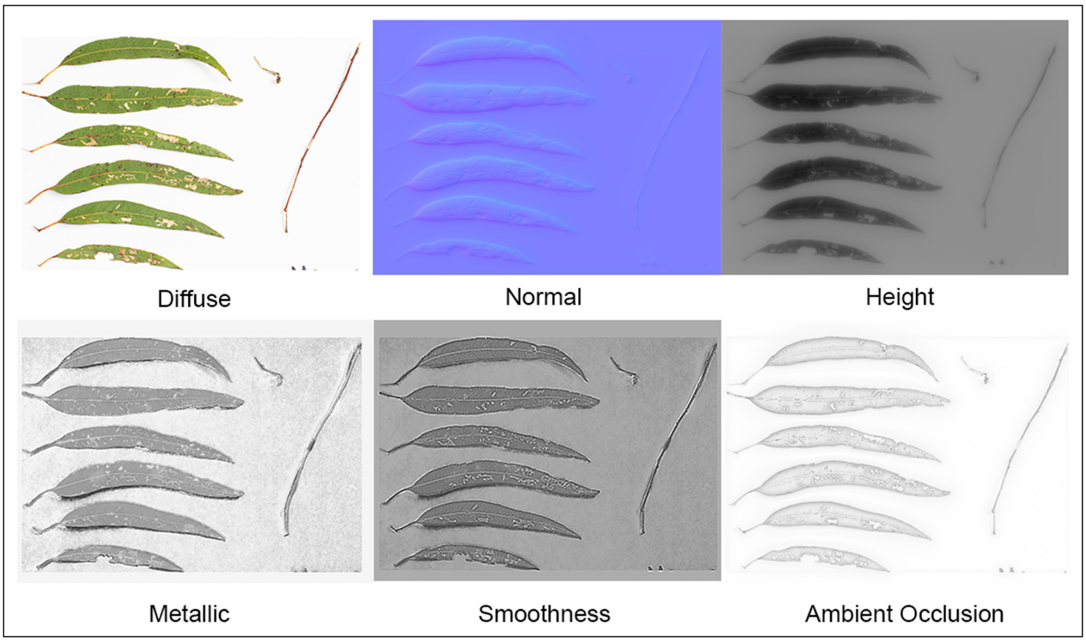

Figure 11 Generated PBR texture maps.

Figure 12 Reference images of leaves (left) and combined PBR textures generated in Materialize (right).

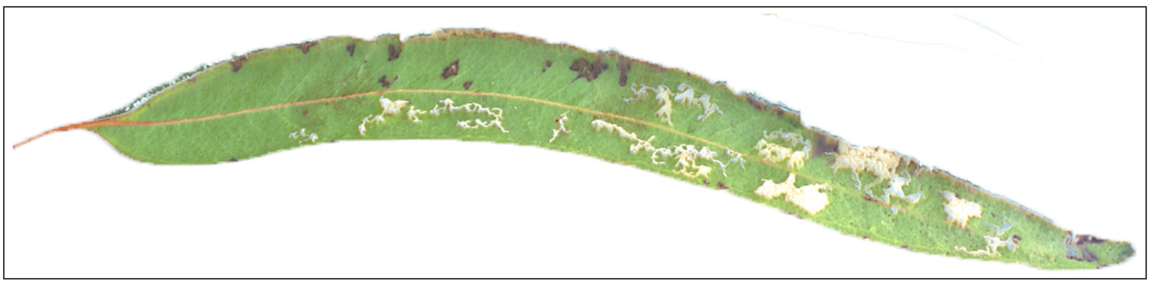

Figure 13 Close detail of combined PBR texture.

Figure 14 Completed branches.

Figure 15 A photogrammetric model of red gum bark.

With the twigs completed, it was then necessary to texture the tree itself. Initially an attempt was made to generate a bark texture from photogrammetric modelling of a section of a red gum visited by the author in Mernda (Figure 15), however it quickly became apparent that the resulting model was far too complex and polygon-heavy for practical use without extensive optimization. Additionally, red gum bark and skin varies in appearance across different sections of the tree, so multiple photogrammetric models would need to be created and blended across different sections of the model. Although textures generated from a photogrammetry model would provide a highly detailed and realistic appearance, at the distance that the trees are visible much of this detail is lost, so the trade-off was made to instead use simple image textures.

Figure 16 Seamless tiling of red gum bark and skin.

Images of red gum trunks were sourced from Wikimedia Commons and uploaded to IMGonline to automatically align them into a 'seamless' pattern that tiles the image, using automatic processing to detect and minimise sharp transitions between the tiles. This image was downloaded and imported into Adobe Photoshop Classic 11.5 where the clone stamp and smudge tools were used to obfuscate noticeable seams that were not resolved by IMGonline's processing. The final texture exported has minimal noticeable seams, allowing it to be wrapped, stretched, and repeated as necessary across the tree trunks without clearly detectable repetitions and transitions which would appear clearly unnatural and disrupt the immersive experience of the viewer (Figure 16).

With the texture applied to the modelled trunks and the branches created, it was necessary to combine them. This was completed using Blender's internal particle system, which allows for objects to be procedurally emitted from selected surfaces (Álvarez-Cedillo and Almanza-Nieto 2010). Blender's weight paint tool was used to manually paint sections of the branches that should have leaves and branches emitting, using reference images to guide the relative amount appropriate for different sections of the tree. This process was repeated with alterations using the same textures and assets to create a variety of red gum models (Figure 17). This workflow allows for the creation of realistic appearing trees with varied branches and leaves which interact with the lighting to cast realistic shadows and reflections (Figure 18).

Other Vegetation

Although not having the same cultural significance to Mernda as red gums, wattle bushes are also native to the region (Robinson 2020; Ellender 1991: 13). Wattle was used as a resource by Wurundjeri groups in the creation of axes and the production of resin adhesives (Griffin et al. 2013: 60–61), and was used by colonial settlers in the wattle-and-daub construction technique (The State Library of New South Wales 2009). Manna gums are likewise present in the Mernda landscape, representing the dominant species in dense forests on the Silurian sandstone terrain. By the period of the reconstruction much of the remaining landscape had been cleared of native vegetation for pasturing and bushfire control, with

Figure 17 Render of red gum models.

Figure 18 Modelled red gums placed into a 3D modelled Blender environment.

introduced grass species overtaking native murnong and grassland. Reeds and rushes remained prevalent along the waterline (Ellender 1991: 8–14).

These plant forms were created using the same process as the red gums (Figure 19), with collected samples photographed; photographs used to create PBR texture maps; trunks created using the Sapling Tree Gen add-on; leaves, flowers, and gumdrops modelled, textured and applied to the trunks using a particle system. Grass blades were modelled individually using the same process as tree leaves, and a randomiser modifier was used to collate them into clumps that could be placed over the landscape.

These natural elements were imported into a Blender file containing a digital elevation model (DEM) of the region which had been converted into shapefile (SHP) using the software package QGIS Desktop 3.12.3 (QGIS 2022). The landscape was weight painted with individual particle systems for the manna gums, grass, and red gums following the landscape units identified and mapped by Ellender (1991: 12). Low polygon duplicates of the manna gums without leaves attached were placed behind the standard models in areas where the canopy was no longer visible and grass placement was restricted to areas visible to the camera to reduce processing strain. The landscape itself was textured with dirt, marsh, grass, and understory PBR textures applied using a mosaic rotation and noise mapping node (Barber 2022). A reflectively shaded plane modified with ripples was used for the Plenty River water. With the terrain complete (Figure 20), the buildings and objects could be placed appropriately on the DEM derived landscape and cameras placed to render out stereoscopic images.

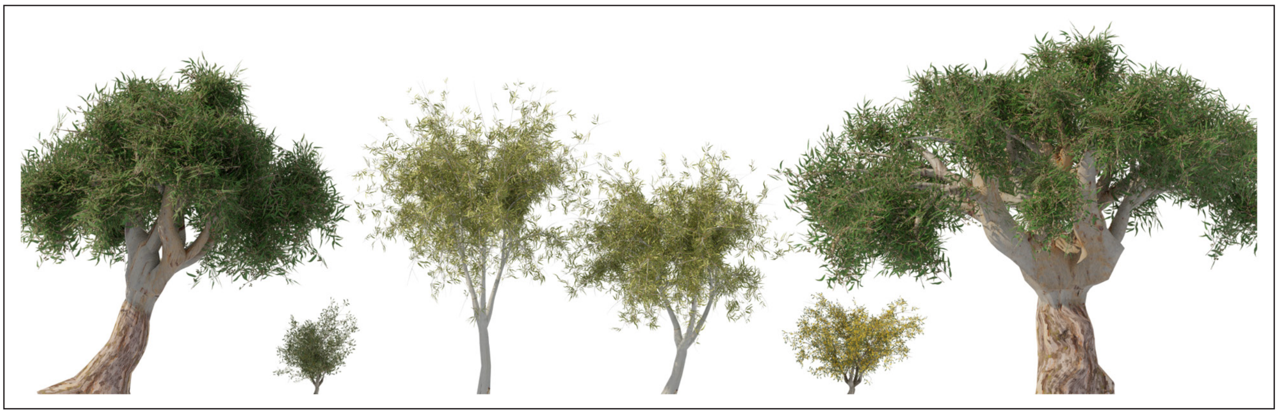

Figure 19 Rendered wattles, manna gums, and red gums.

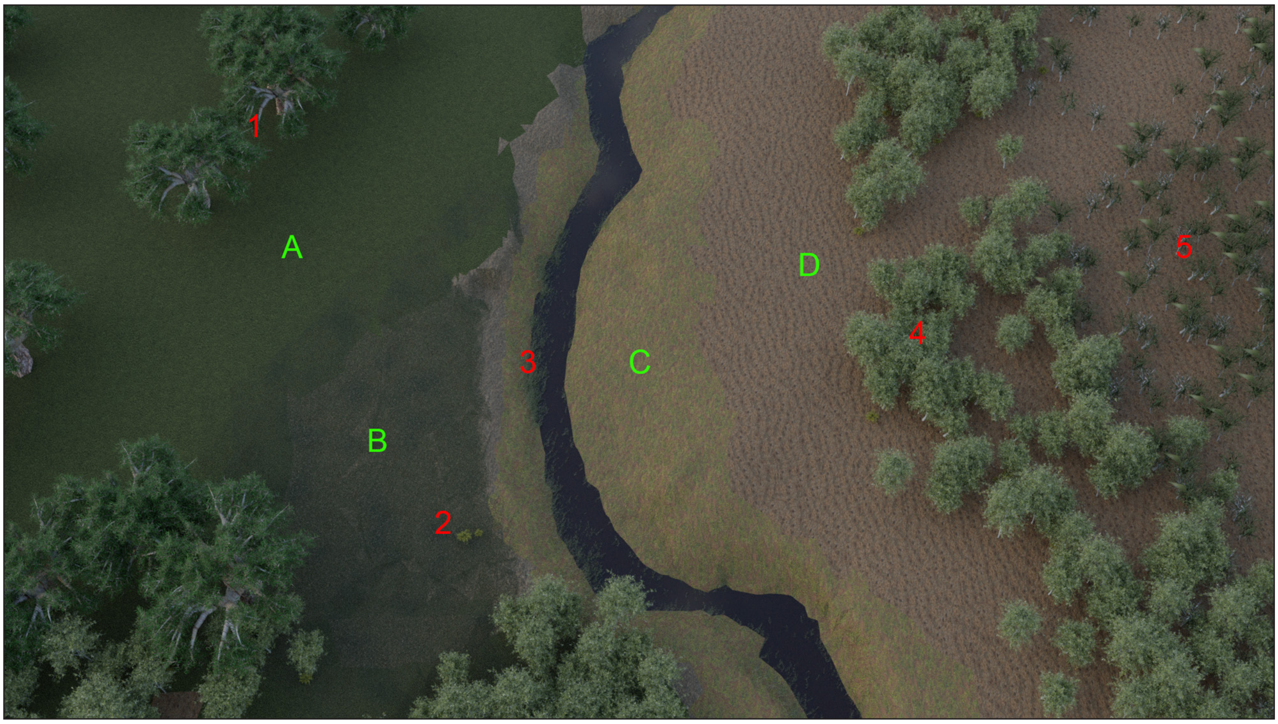

Figure 20 The terrain and natural elements as seen from above. (1) Red gums (2) wattle bushes (3) rushes (4) high detail manna gums (5) low detail manna gums. (A) Grass texture (B) grass particle system (C) marsh texture (D) forest floor texture.

2.3 PRESENTATION

Once the terrain was complete and the buildings and objects were placed into the scene (Figure 1), cameras within Blender were used to render 360° stereoscopic images which could be viewed in a VR headset or displayed as 360° videos on flatscreen monitors. Cameras were placed in strategic positions that displayed the cultural material while obscuring or minimising the visibility of low polygon models or areas of the terrain that had little or no grass particle systems: one near to the cottage (Figures 21 and 22), with another placed beside the mill. The rendered images were imported into the virtual tour software package 3DVista, which was used to create interactive virtual reality experiences.

3DVista is an interactive virtual tour software package which allows for the integration of virtual environments with embedded video, audio, hyperlinks, and pop-up windows for extra information. While primarily intended for the creation of remote real estate tours, the software has seen educational applications in laboratory safety training (Viitaharju et al. 2021), physiotherapy (Law et al. 2018), and Indigenous perspectives on natural landscapes (Hearn 2020). In representations of heritage, the software has been used in service of tours depicting archaeological heritage at Poggibonsi (Bertoldi 2021), San Menna (Trizio et al. 2019), and Egnatia (Cantatore, Lasorella and Fatiguso 2020) in Italy. The tour package allows for stereoscopic images to be imported and displayed as wrap-around panoramas through a VR headset, with panoramas linked by hotspots to facilitate a sense of movement. The pop-up features, termed 'hotspots' by 3DVista, allow users to investigate elements of their environment in closer detail, while the incorporation of audio and artificial lens flare from the 'sun' increase a sense of immersion. Directional audio clips of Australian bird song, running water, fire crackle, and a mill wheel grinding were added such that they activate when the viewer is looking in a particular direction: the grinding audio plays only when facing the mill, the water when facing the river, etc.

The two rendered images acted as viewpoints for users to experience the reconstructed virtual environment (Figure 21). Beside the cottage, users could view the Yan Yean Aqueduct, the reconstructed cottage, and see the mill from a distance. Hotspots at this viewpoint contained additional information regarding the cottage, the bottle of Perry Davis Painkiller, the marble, glass beads recovered during excavation, and the surrounding environment. Once finalised and edited, these displays are intended to be made freely available to local schools, libraries, cultural institutions, and historical societies.

3. CONCLUSION

The Mernda VR Project is an early experiment of the capacities of 3D modelling to represent rural Australian heritage (Figure 22), which has to date been under-explored through this medium. The project sought to explore how these technologies can represent more humble heritage sites which are frequently under-represented, underfunded, and at risk of damage or destruction. The project aims to make the environment itself an important element of the reconstruction, and harness the technological capacities of photogrammetry and 3D modelling software to create life-like hypothetical representations of the past. Importantly, this work was all completed by the author, learning the methodologies of 3D modelling as he worked, demonstrating that higher quality representations can be completed in a short timeframe through the collaboration of archaeologists and professional 3D modellers, of which Australia has many. The option to create reconstructions such as these would be relatively inexpensive while opening opportunities for the easy distribution and preservation of high-quality, engaging, and informative representations of rural heritage, and ought to be considered as a viable option for heritage outreach to the public. Future research is planned to qualitatively and quantitatively examine the capacities of these representations for improving learning and engagement outcomes in school settings, as well as exploring more fully immersive and interactive environments using video game engines in place of virtual tour software.

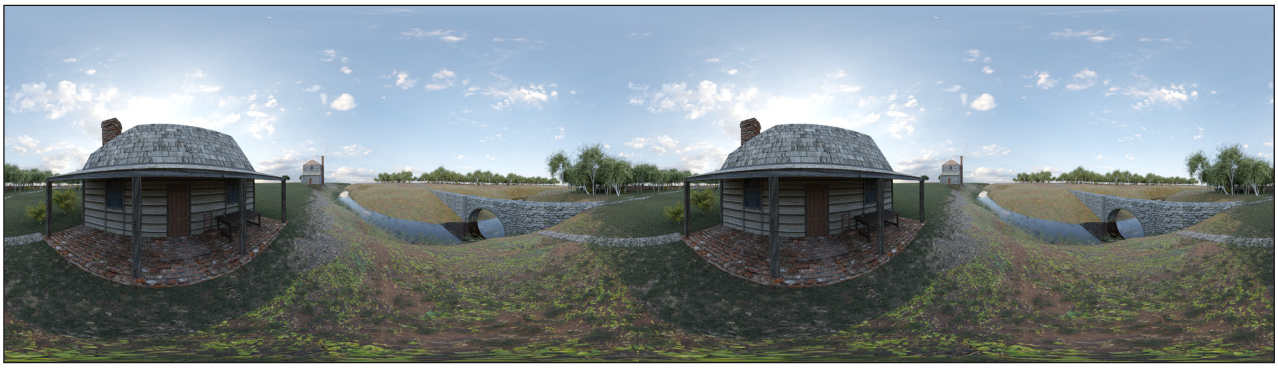

Figure 21 Stereoscopic image from the cottage viewpoint.

Figure 22 Render of the mill and cottage.

DATA ACCESSIBILITY STATEMENT

The complete Blender files and 3D Vista experience are available for download at: Keep, T. 2022a. Mernda VR Project: Blender and 3D Vista Files. Figshare v.

A video render of the photogrammetry models can be found at https://vimeo.com/698885180. The image sets used for processing, Agisoft Metashape project files, and 3D object files are available for download at: Keep, T. 2022b. Figshare DOI: 10.26188/21259494 and 10.26188/21266352.

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COMPETING INTERESTS

The author has no competing interests to declare.

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